LSST Observing Strategy and Supernovae

Ph.Gris[1], N.Regnault[2]

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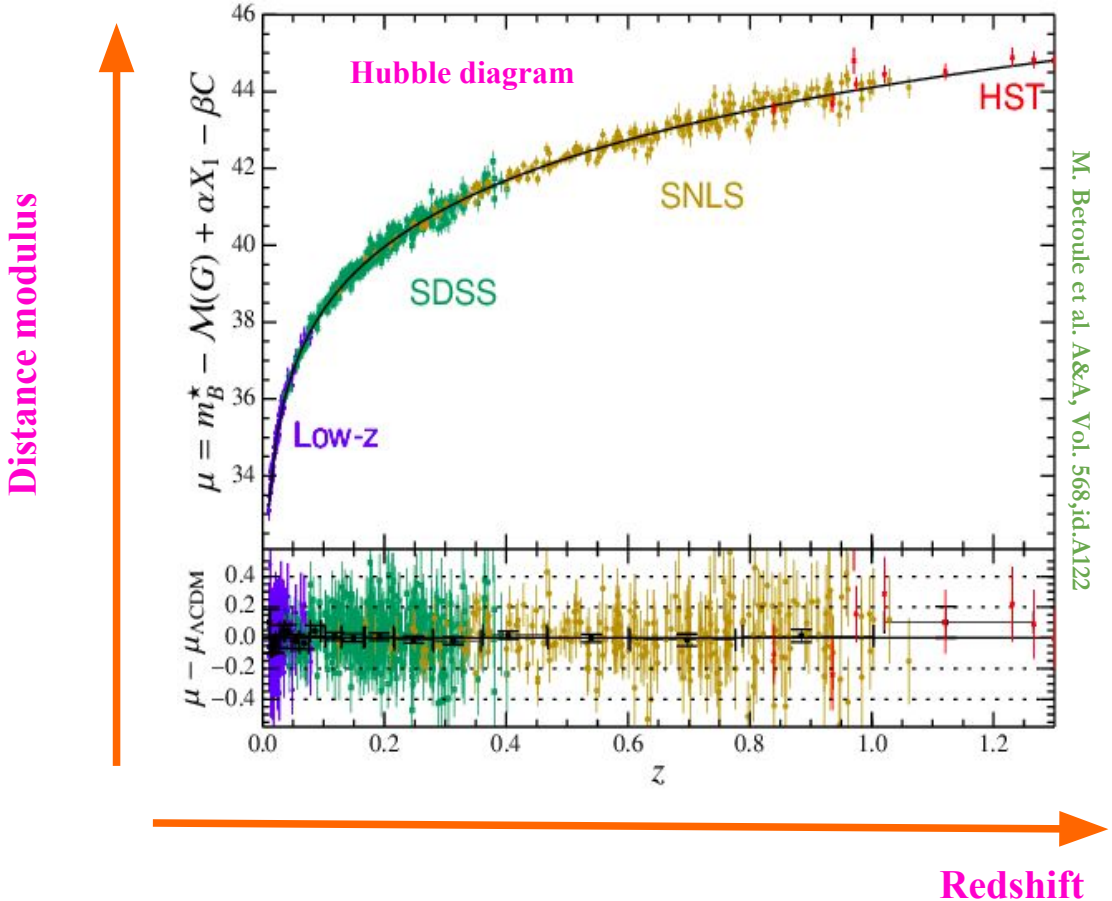
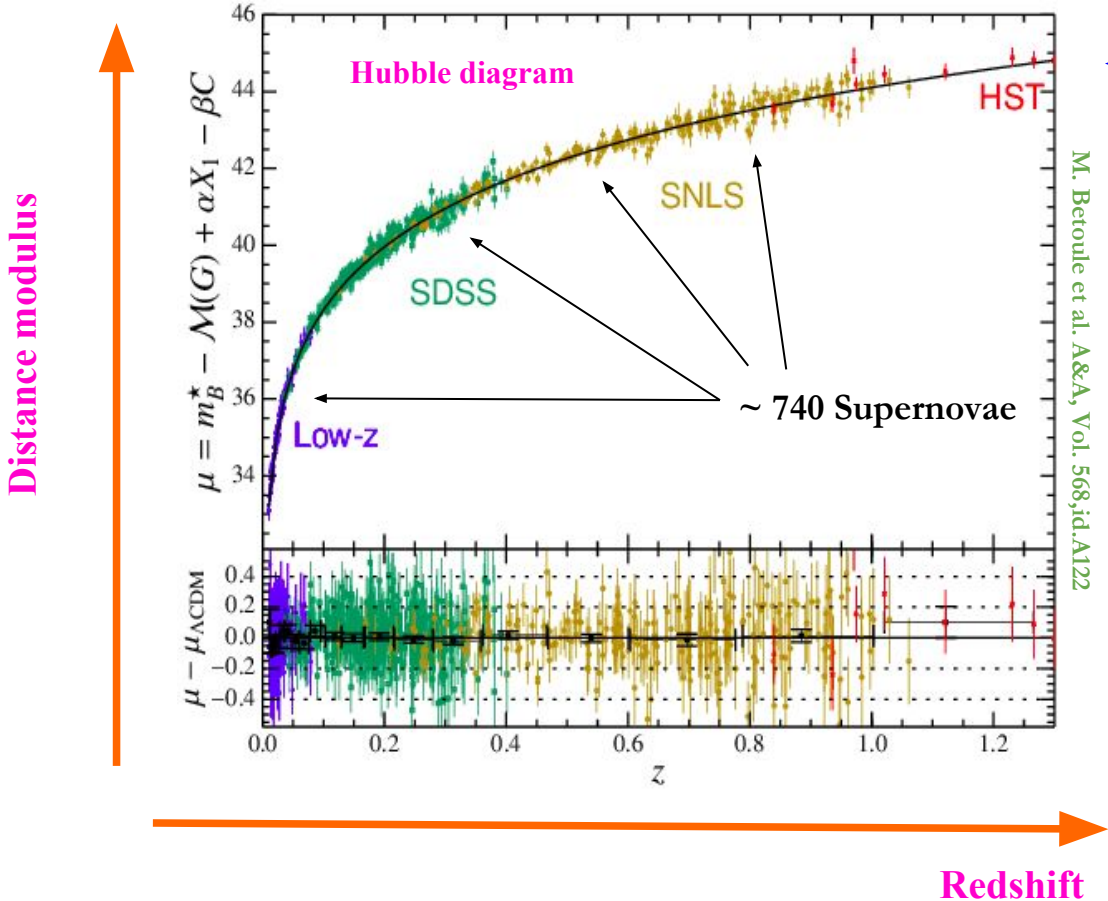
1 Laboratoire de Physique de Clermont IN2P3/CNRS
2 Laboratoire de Physique des Hautes Energies IN2P3/CNRS

Supernovae and Dark Energy



M. Betoule et al. A&A, Vol. 568,id.A122

Supernovae and Dark Energy



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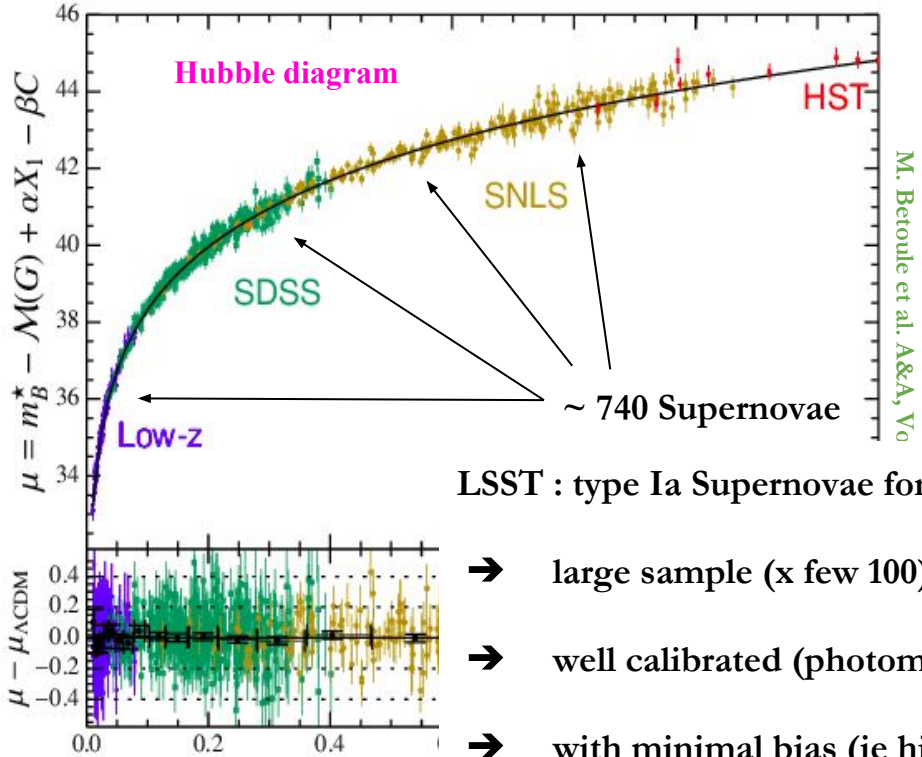
Cosmology (fit)

-> Dark Energy constraints

Supernovae and Dark Energy



M. Betoule et al. A&A, Vo

Distance modulus

Redshift

~ 740 Supernovae

Cosmology (fit)

-> Dark Energy constraints

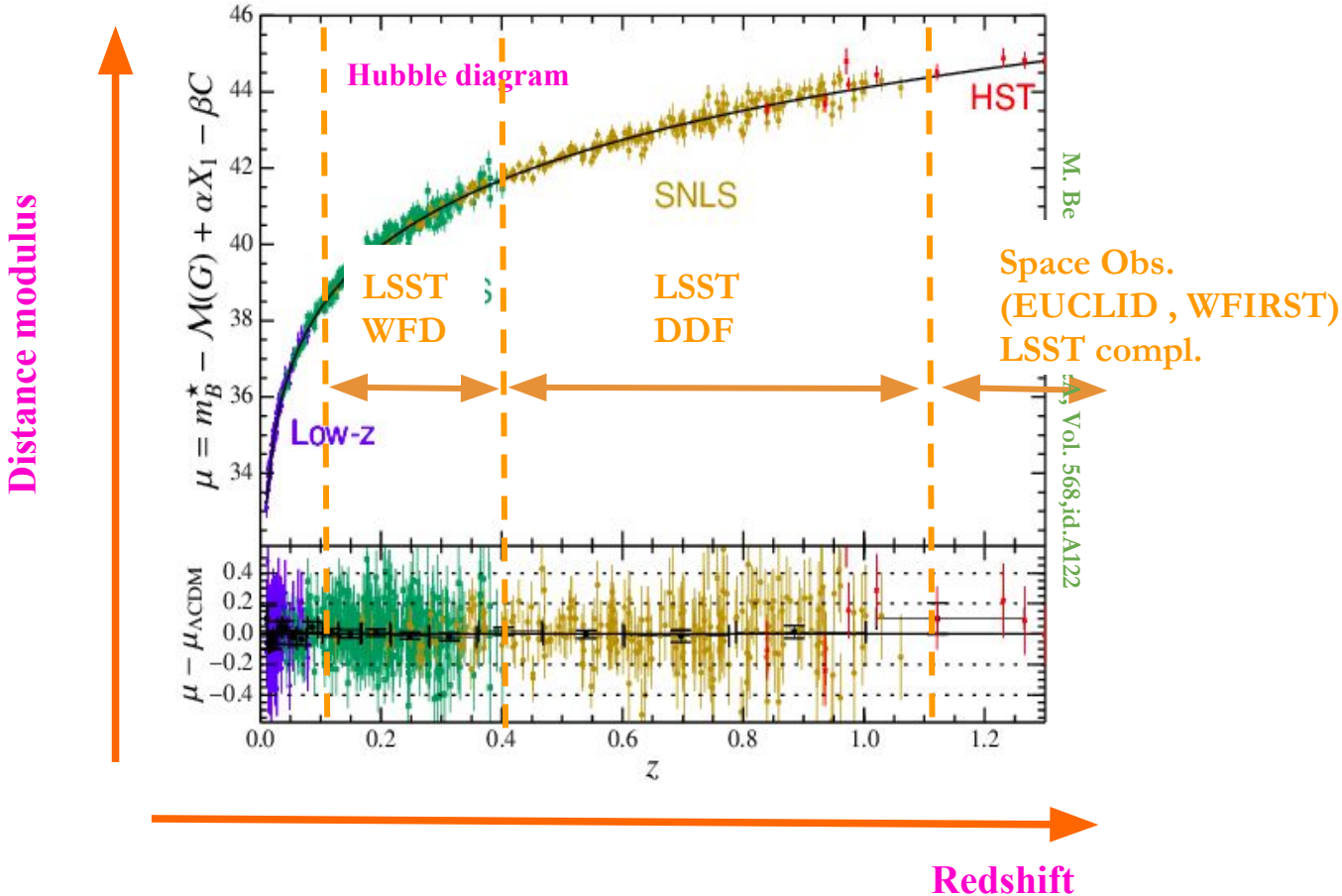
LSST : type Ia Supernovae for Hubble diagram

➔ large sample (x few 100)

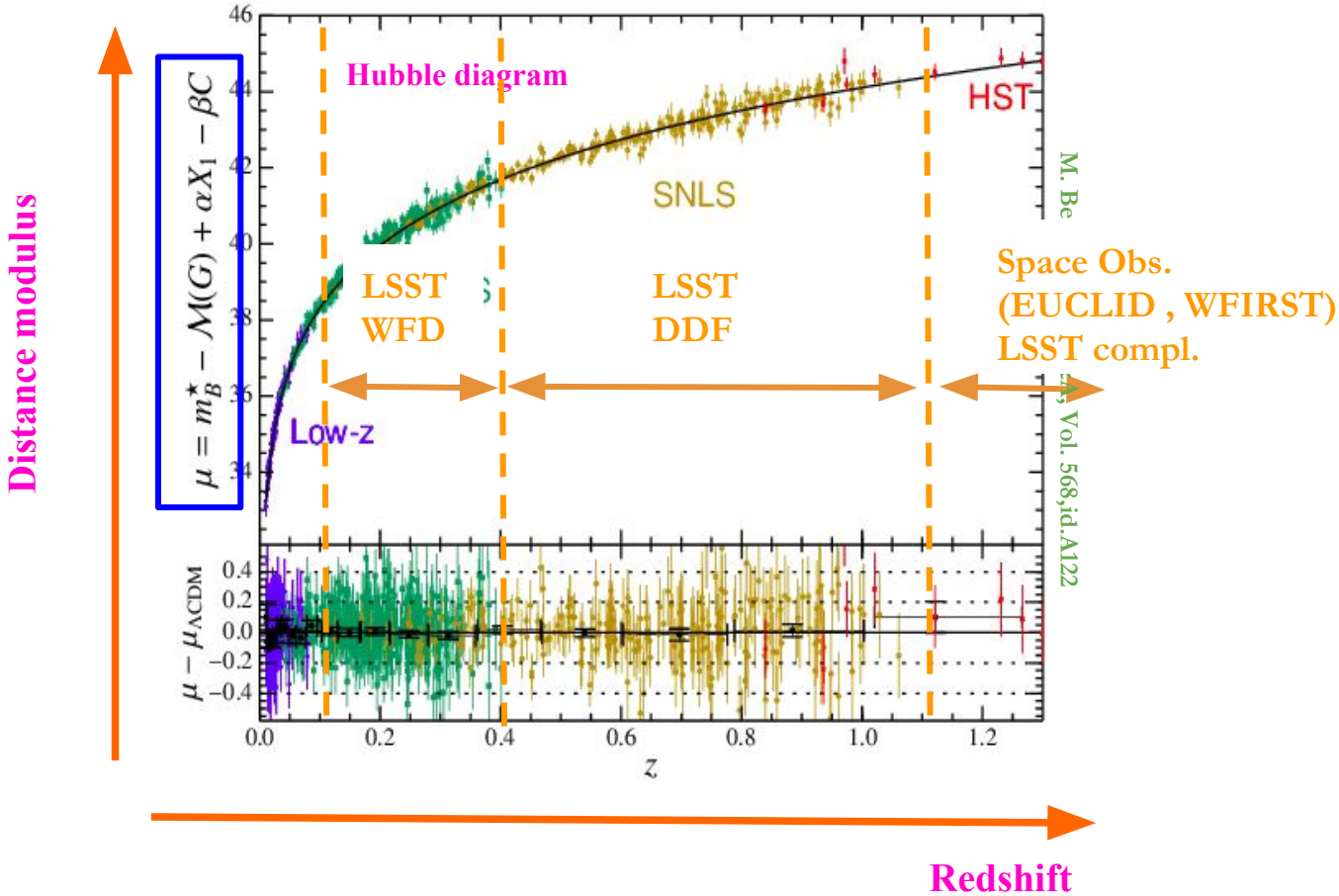
➔ well calibrated (photometry) well measured

➔ with minimal bias (ie high redshift completeness)

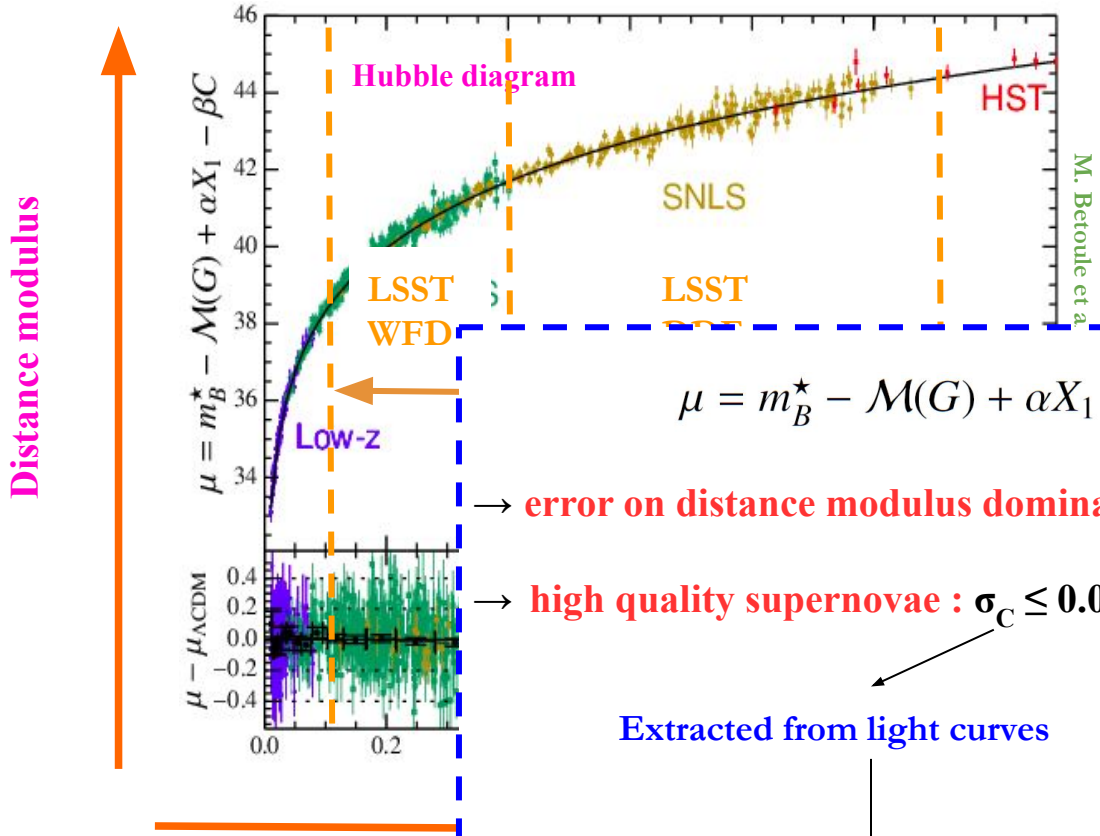
Supernovae and Dark Energy



Supernovae and Dark Energy



Supernovae and Dark Energy



$$\mu = m_B^\star - \mathcal{M}(G) + \alpha X_1 - \beta \boxed{C}$$

→ error on distance modulus dominated by σ_C

→ high quality supernovae : $\sigma_C \leq 0.04$ ($\sigma_\mu \leq 0.1$)

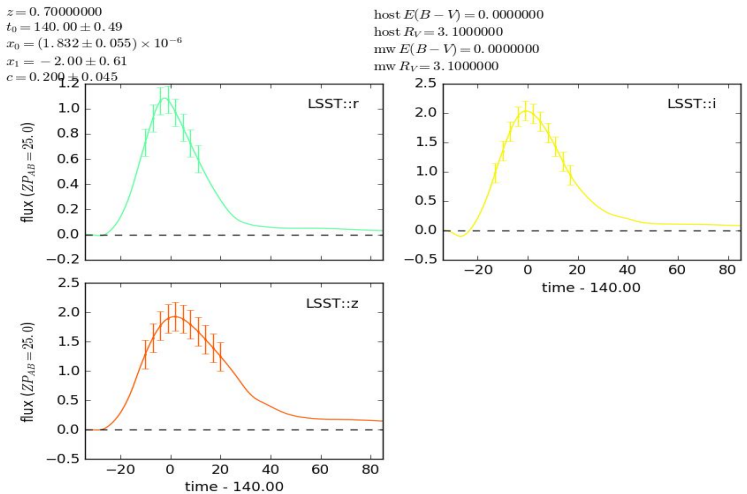
Extracted from light curves

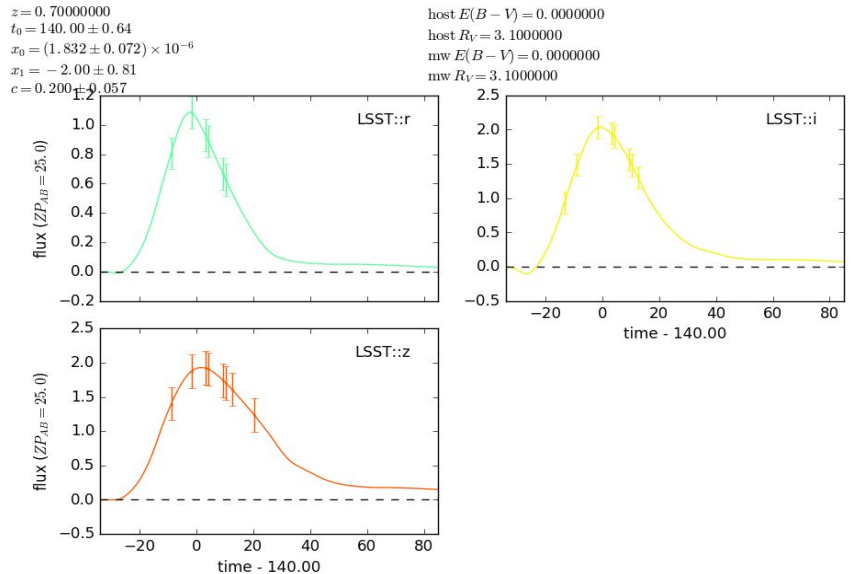
Quality -> Observing Strategy

Main parameters driving SN science

Parameter	Impact	Typical value
cadence +multiband observations	Light curve quality (SN parameters estimation)	median: 3 days-1 with limited variations
season length	Number of SN collected	170-180 days
depth	High z detection	5-σ depth ~ 26.5, 26.2, 25.6, 24.7 for r, i, z, y bands (DDF)

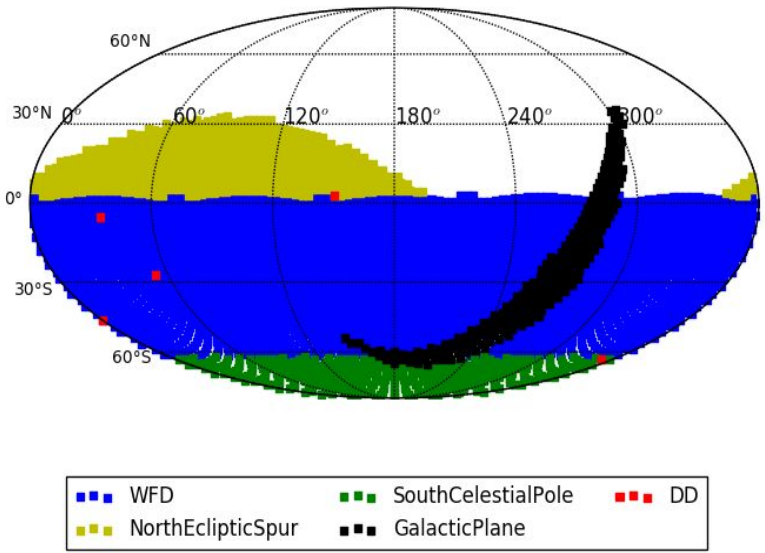
The goal : collect a large and unbiased ($z \leq 0.8$ DDF) sample of well measured ($\sigma_C \leq 0.04$) type Ia supernovae.





LSST Observing Strategy

Total number of visits : ~ 2,450,000
(1 visit = 30s exposure time)



3 types of surveys:

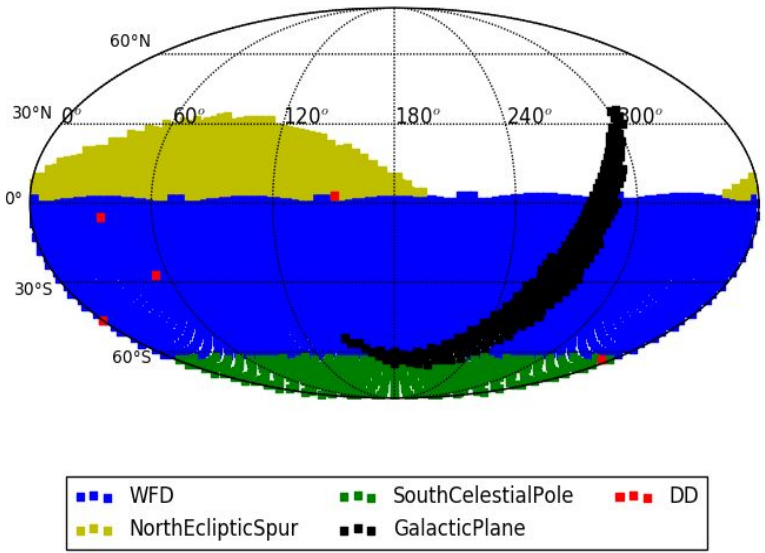
- universal (WFD) ~ 90% -> Supernovae
- mini-surveys : ~5%
- Deep (DDF) : ~5% -> Supernovae

Survey	Science
WFD	Parallaxes, proper motions, asteroids, transients,...
mini-surveys	Magellanic clouds, asteroids (NEA, MB)
DDF	Transients (Supernovae)

Supernovae: strong constraints on cadence, depth, season length, area.

-> 90 to 95% of the survey (WFD+DDF)

LSST Observing Strategy



LSST observing strategy is not defined yet.

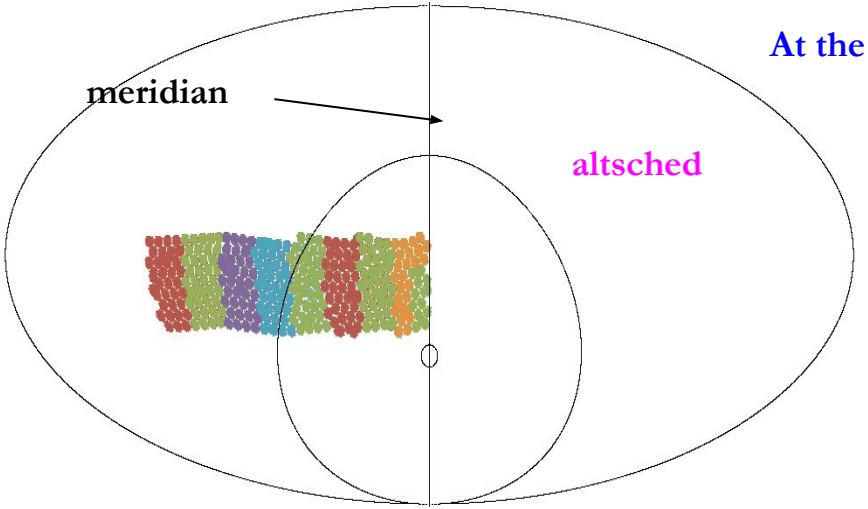
Open questions:

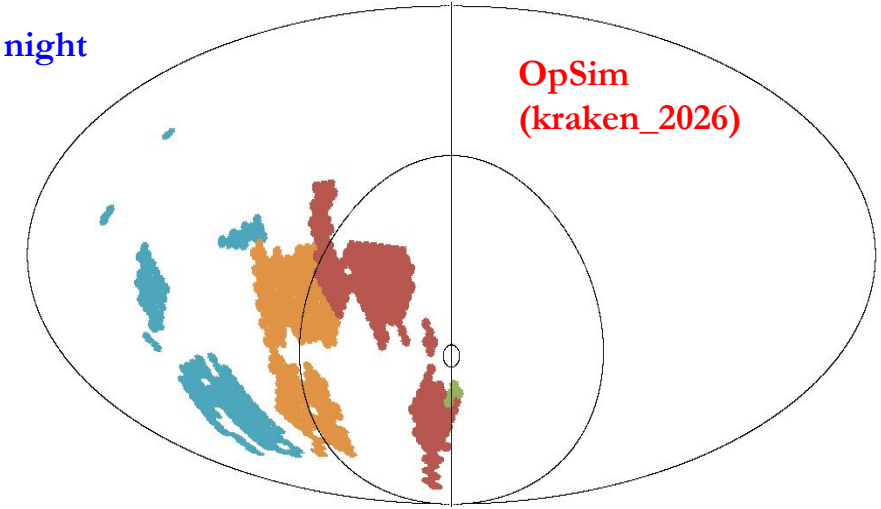
- **Fraction of each type of survey ?**
- **Area?**
- **Depths (per band)?**
- **Cadence (per band)?**
- **Filter allocation (per night or globally)?**
- **How should the sky be observed ?**
- **Exposure times?**
- **Season lengths?**
- **...**

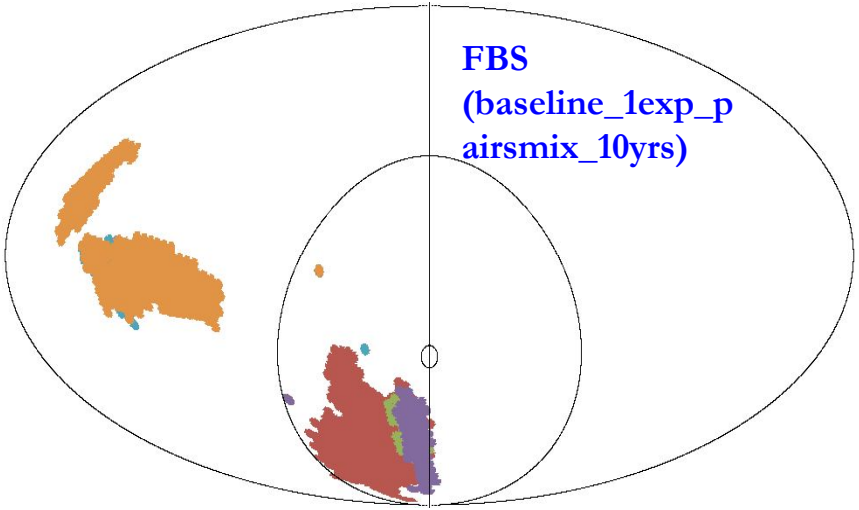
We have quite a lot of simulations with these parameters varying. We use sets of metrics to estimate which observing strategy are optimal for SN science.

LSST Observing Strategy - Methods to scan the sky

At the end of a night





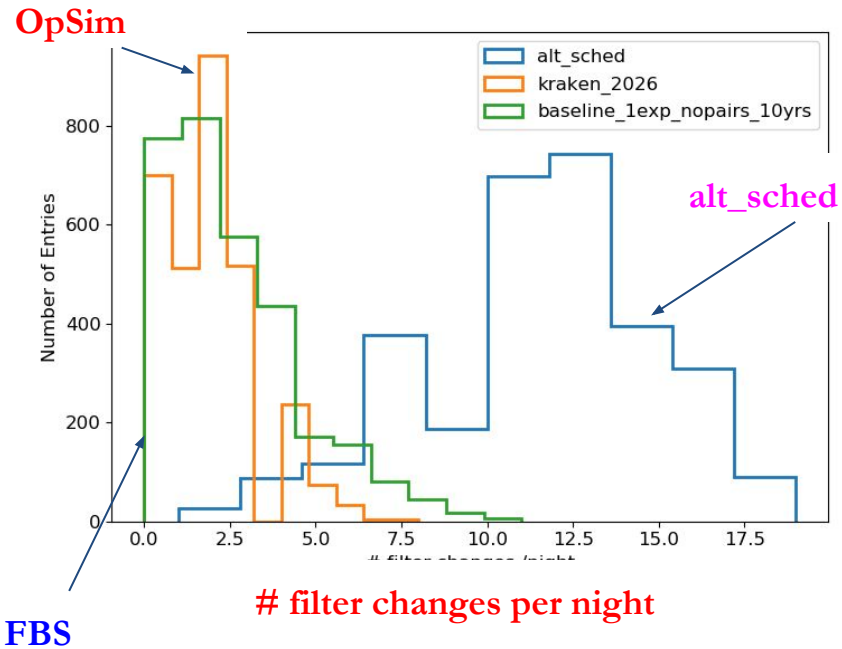


OpSim : greedy algorithm optimizing observing conditions and minimizing slew time

alt_sched: systematic scans at the meridian; dense parts of the sky per night; lots of filter swaps.

FBS: markov chain decision process (slew time, image depth and desired foot print)

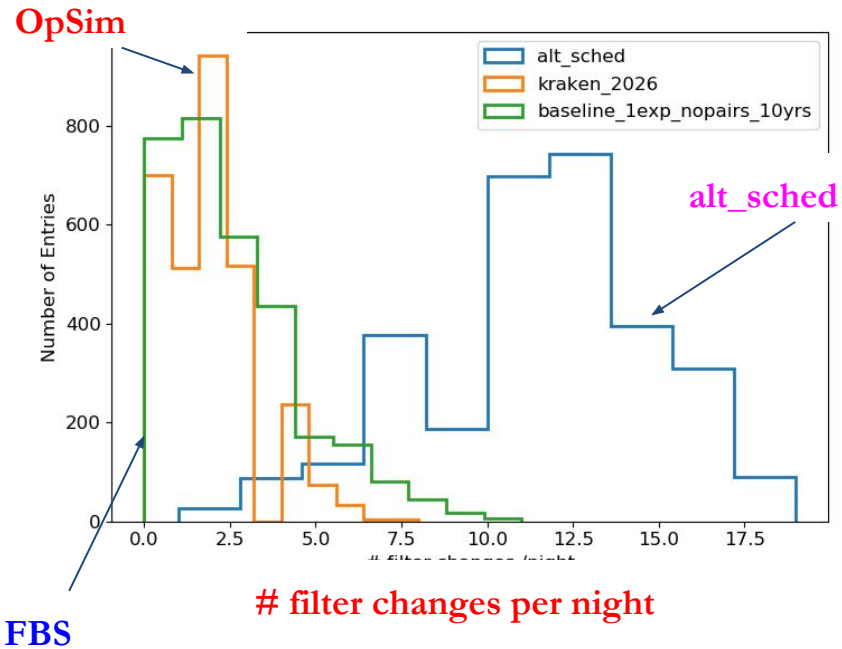
LSST Observing Strategy - Methods to scan the sky



filter allocation

	OpSim	FBS	alt_sched
u	7%	7%	8%
g	10%	10%	10%
r	21%	22%	28%
i	22%	22%	18%
z	20%	20%	26%
y	18%	18%	9%

LSST Observing Strategy - Methods to scan the sky



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g	10%	10%	10%
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i	22%	22%	18%
z	20%	20%	26%
y	18%	18%	9%

	g	r	i
alt_sched	10.5	4.0	6.0
FBS	17.9	9.0	10.5

Median cadence after 10 years

LSST Observing Strategy - Metrics and Supernovae

- **A set of metrics to assess impact of observing strategies:**
  - **Number of well-sampled supernovae (N_{SN},z_{limit})**
  - **Cadence metric**
  - **Rate of SN with SNR>=SNR_{median}**
  - **Figure of Merit (w0,wa)**
  - **Photometric classification**
  - **Peculiar velocity**
  - **…**

- **Most of these metrics do not rely on full simulations (time consumption) but on proxies as precise as possible (trade-off precision/processing time).**

- **Some of these metrics are estimated using two types of supernovae:**
  - **"Faint": (x1,color)= (-2.0,0.2)**
  - **"Medium" : (x1,color) = (0.0,0.0)**

LSST Observing Strategy and SN – Cadence metric

Cadence metric

average 5-σ depth

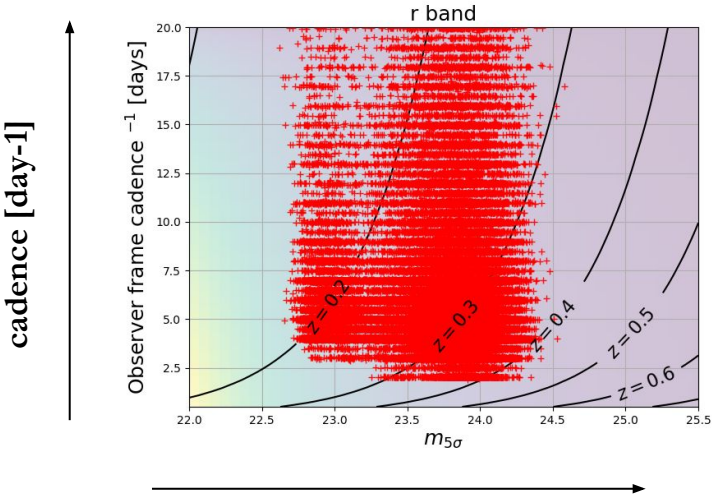
Observing strategy

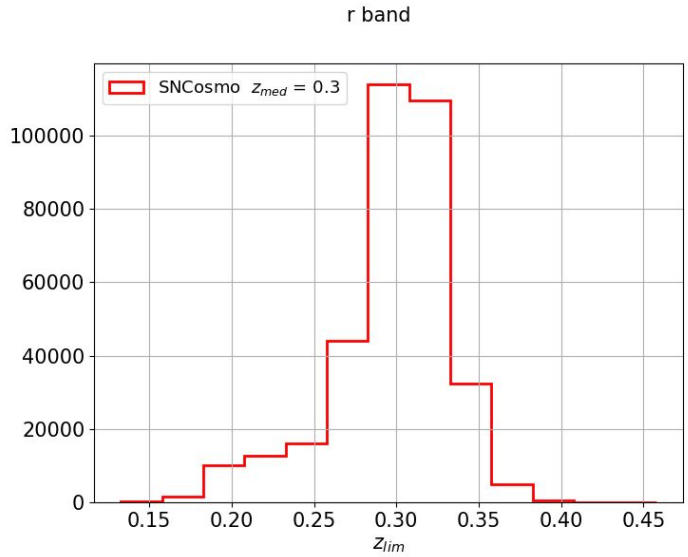
$$f_{|5} < \delta_i >^{-1/2} \leq \frac{5\sqrt{\Delta t}\sqrt{\sum_i L_i^2}}{SNR}$$

average cadence

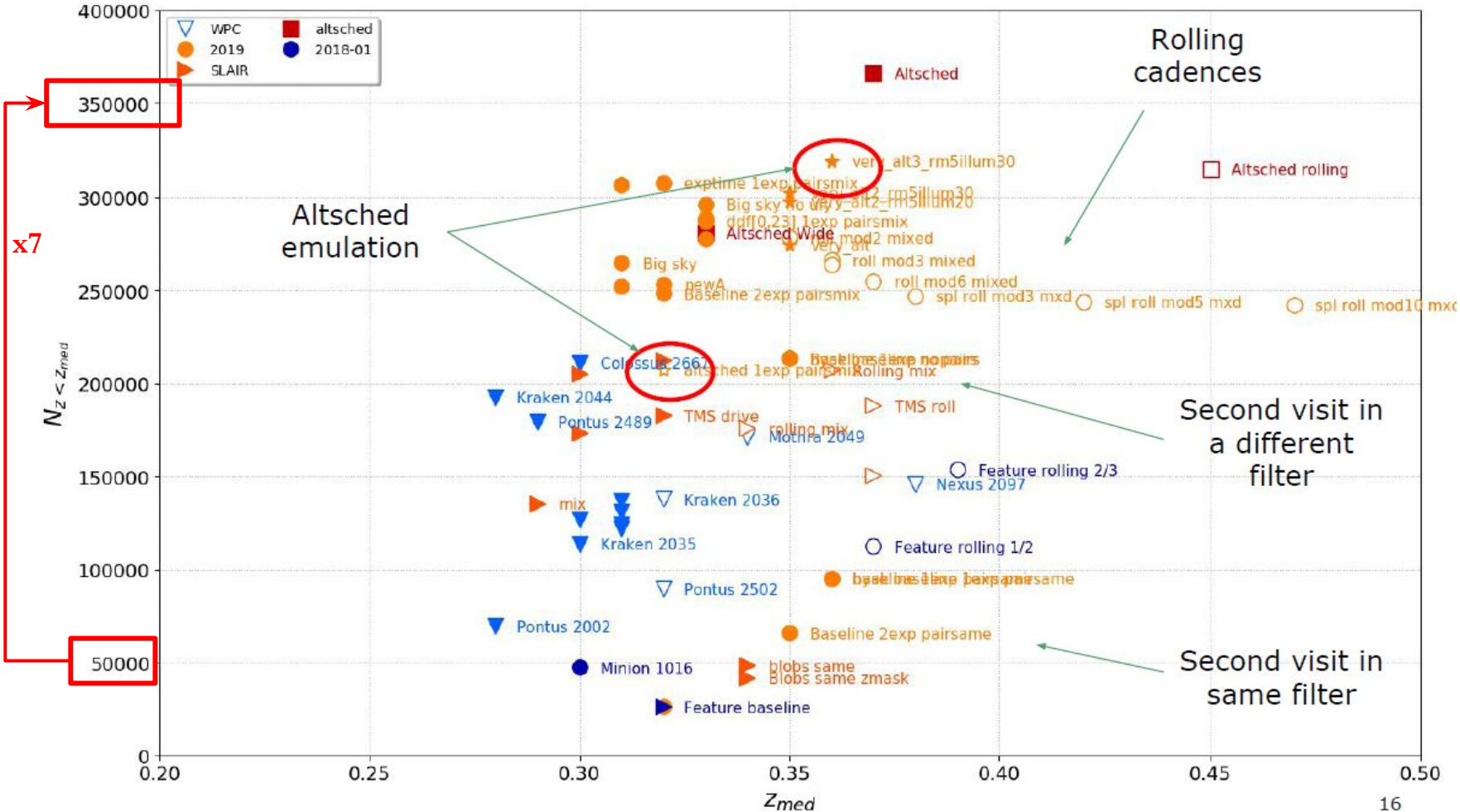
Limit in e/s √day

Supernovae science



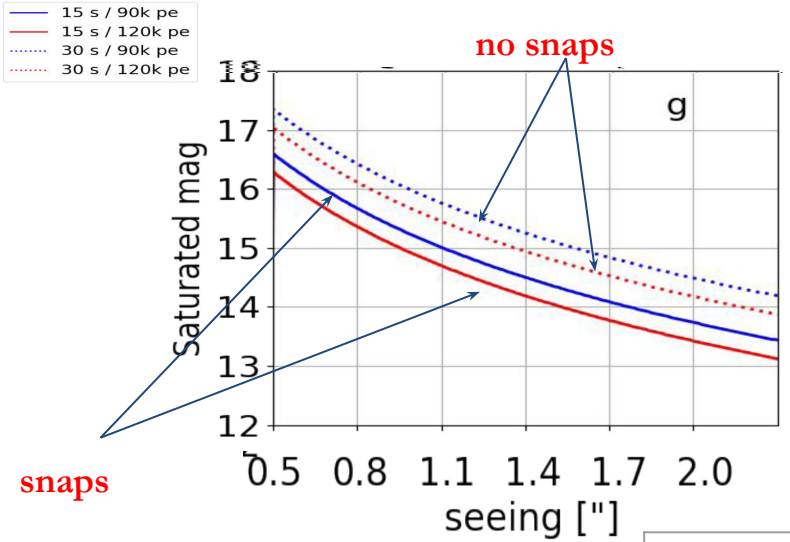


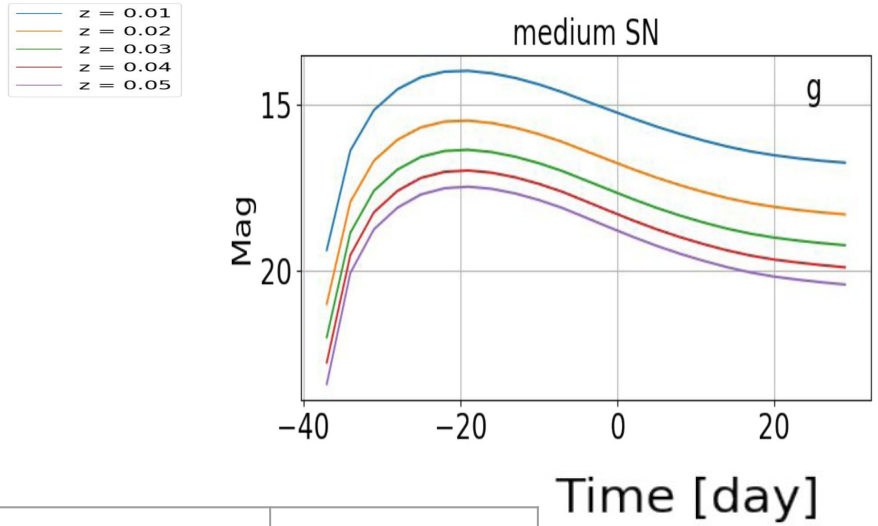
LSST Observing Strategy and SN – Number of well-sampled supernovae



LSST Observing Strategy and SN – Pixel saturation

- snaps (2 exposures of 15 s) vs "no snaps" (1 exposure of 30s)
  -> would allow a gain of observing time (+7%)
  -> But one exposure of 30s increases saturation effects (also depends on the ccd full well)



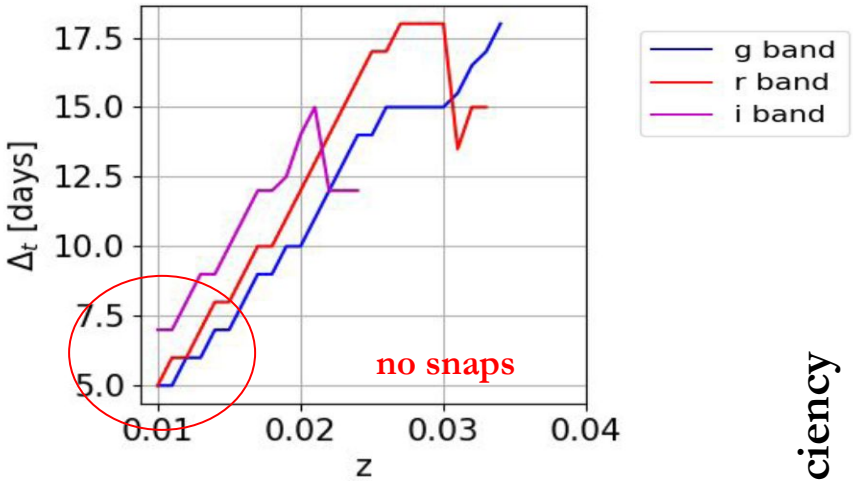


wrt current baseline
exptime=15s, fw = 90 kpe

Exptime (s)	ccd full well(kpe)	Δm_{sat}
15	120	-0.31
30	90	+0.75
30	120	+0.44

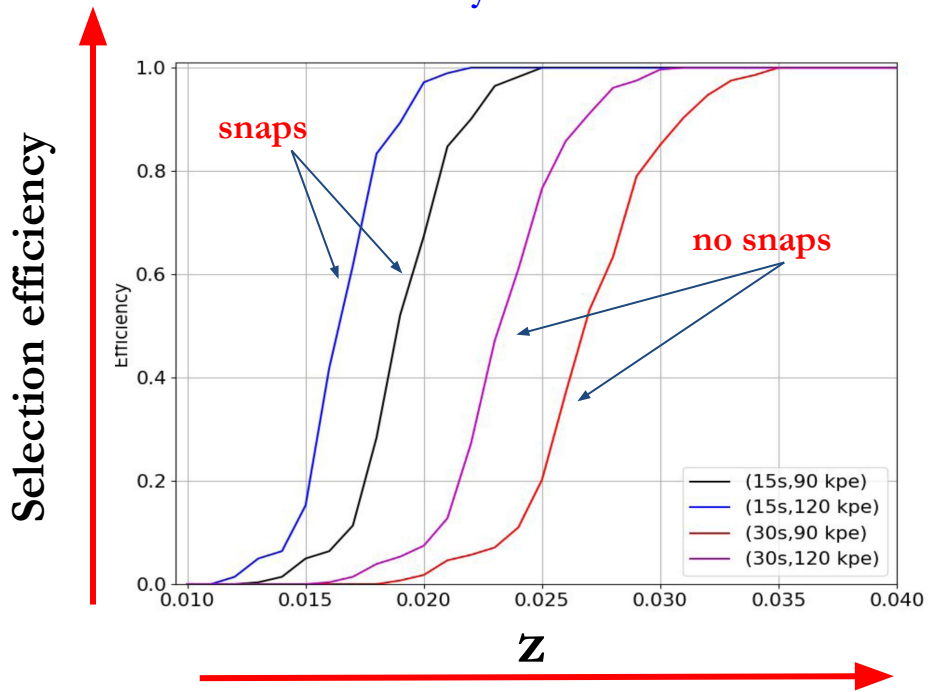
LSST Observing Strategy and SN – Pixel Saturation

Time of saturation

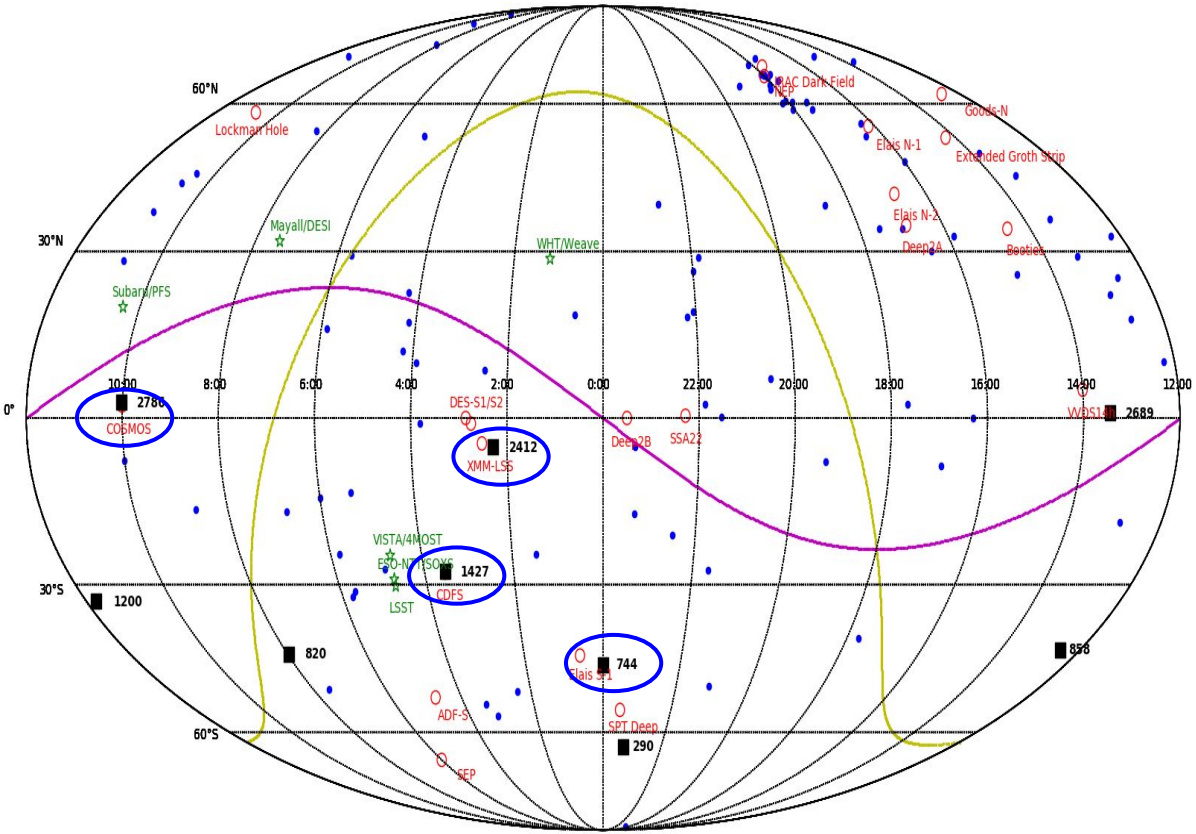


Saturation occurs after 5 to 7 days
-> tight wrt cadence: early identification?

At least 3 LC points
± 4 days around max lumi



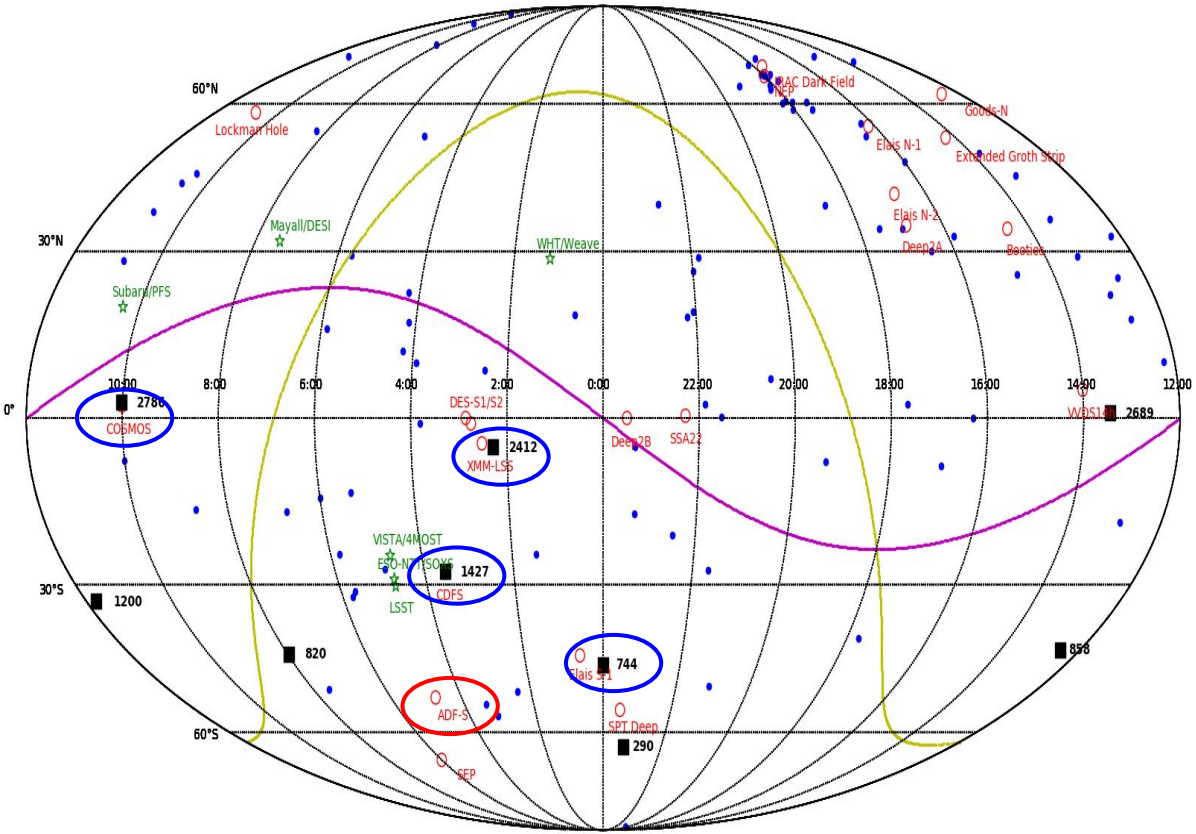
LSST Observing Strategy and SN – DDF



4 fields already selected

Field	(RA,Dec) (deg)
ELAIS-S1	(0.00, -45.52)
CDFS	(53.01, -27.44)
XMM-LSS	(34.39, -5.09)
COSMOS	(150.36, 2.84)

LSST Observing Strategy and SN – DDF



A 5th field overlap with EUCLID and WFIRST

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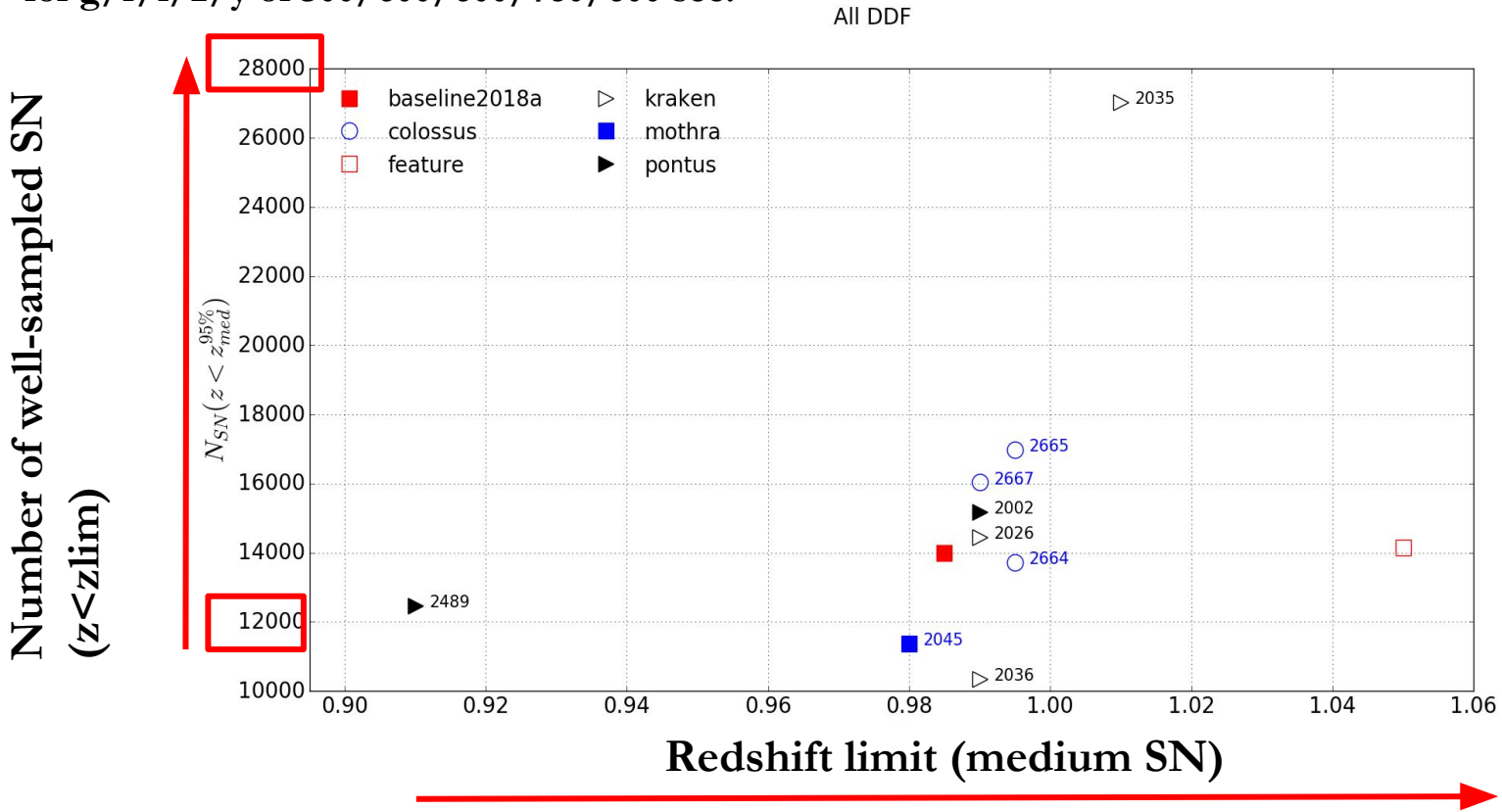
COSMOS	(150.36, 2.84)
Akari South DF	(71.0,-53.3)

LSST Observing Strategy and SN – DDF

- **Observing strategy (in terms of cadence and depth) is not finalized yet.**
- **Constraint: DDF program : 6-7% (upper limit) of LSST survey**
- **Simulations with at least 4 fields (SPT for the 5th) - cadences of about few days/exposure times for g/r/i/z/y of 300/600/600/780/600 sec.**



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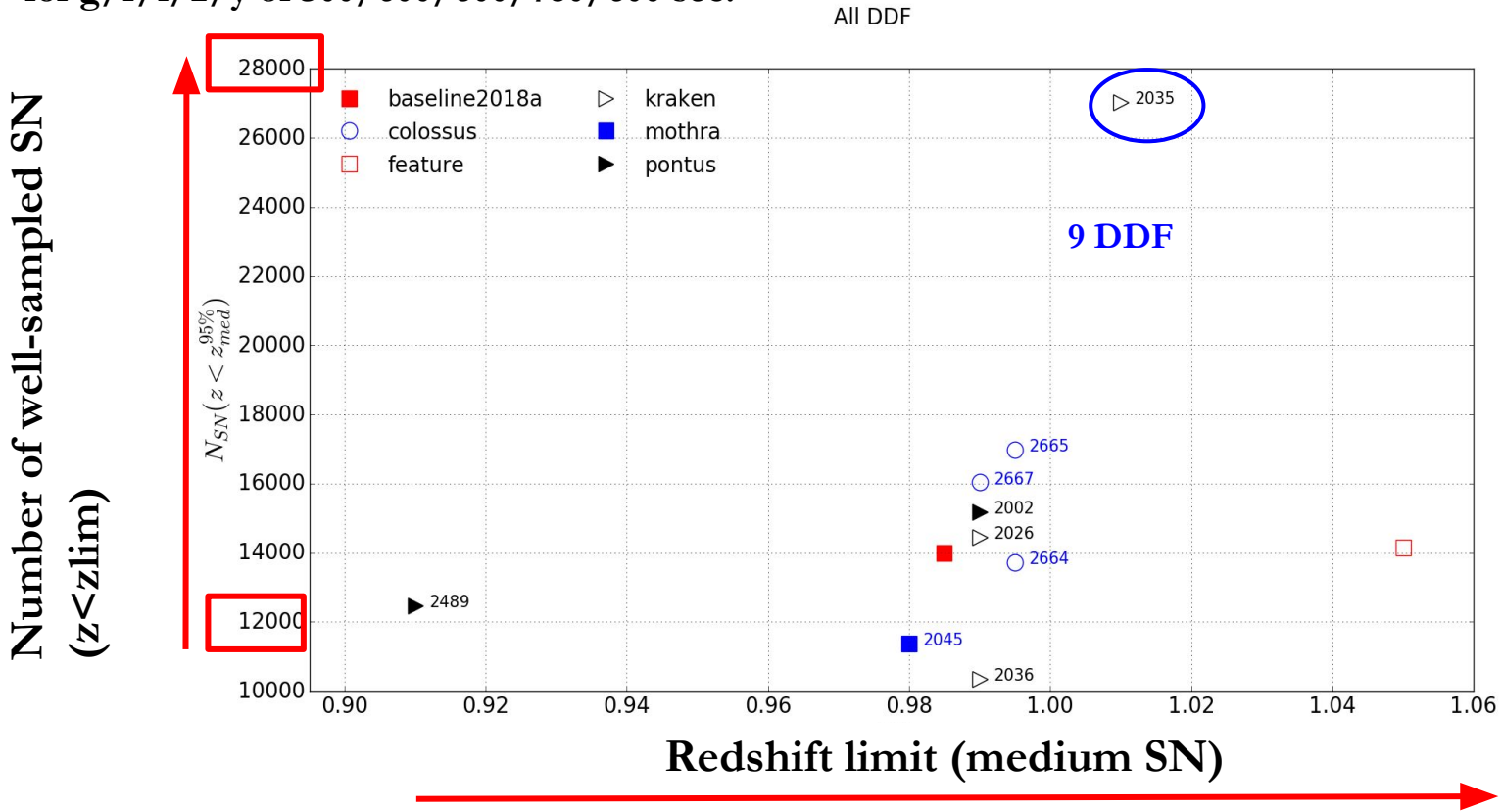

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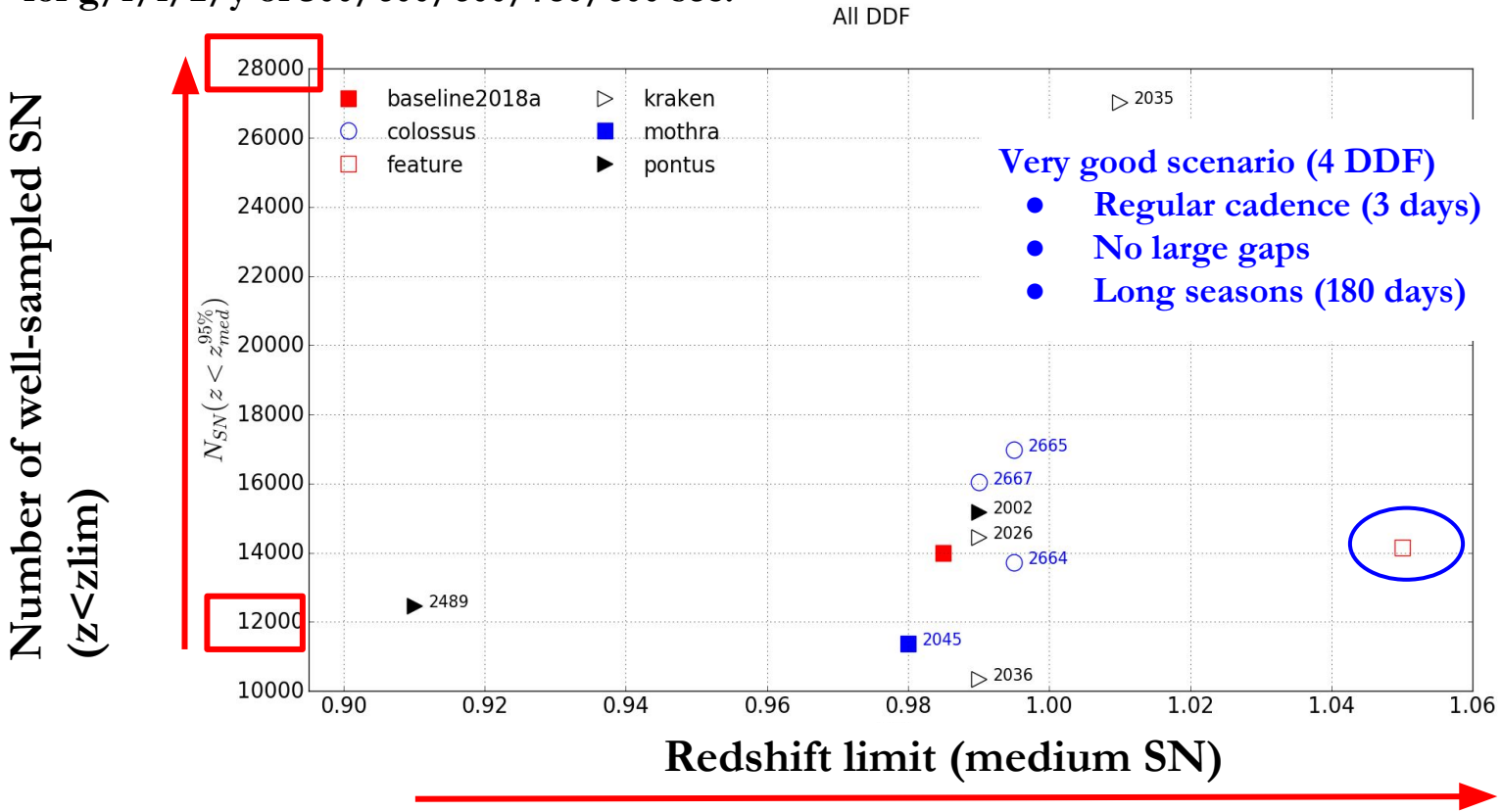
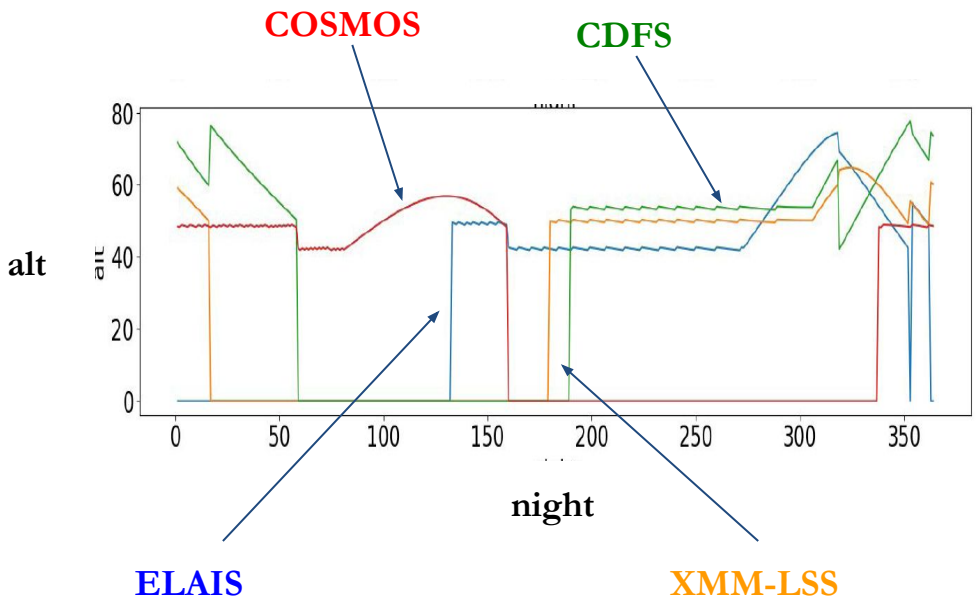


LSST Observing Strategy and SN – DDF

- A new observing strategy has been proposed in arXiv:1812.00516



- High cadence with intertwined band observations
- COSMOS : every night with night1: gri and night2: zy
- ELAIS,CDFS,XMM: every 3 nights with: night1: gri, night2: zy, night3: nothing
- depth: grizy: 2/4/8/25/4 visits
- This would correspond to about 5.7% of the total observing time.

- Simulations of this scenario are being analyzed.
- This scenario may be tuned depending on how the DDF survey will be planed (sharing with AGN)

LSST Observing Strategy and SN – Summary

- **Lots of observing strategies simulated and assessed using SN metrics**

  - **WFD**

-> recent simulations show clear improvements
-> close to a set of scenarios leading to a *large* sample of *well-measured* type Ia supernovae

  - **DDF**

-> limited to 6-7% of LSST survey -> 5 DDF at max
-> scenarios to be tuned (cadence, depth, compl. EUCLID/WFIRST, sharing with AGN)

  - **Saturation**

-> low-z SN (effects up to $z \lesssim 0.030$-0.035)
-> better to have 2x15s exposures (effects up to $z \lesssim 0.020$-0.025)

  - **Early identification/spectroscopic follow-up**

-> early identification of SN has to be studied to define the spectroscopic follow-up program

LSST timeline for survey strategy

Call for white papers	june 30, 2018
White paper submitted	Nov 30, 2018
List of to-be-simulated survey strategies	April 2019
Simulated survey strategies available	End of 2019
Survey Strategy Committee (SSC)	Early 2020
SSC report on official initial LSST survey strategy	Early 2021
Baseline simulation of initial LSST survey strategy	Mid 2021
Start of LSST operations	2022
Regular survey reviews by the SSC	2022-2032